Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Advisory Committee on Reactor Safeguards Review of Reactor for the APR1400 Design Certification

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1. Introduction

KHNP is pursuing the U.S.NRC design certification (DC) of the APR1400 since 2009. The U.S.NRC started review according to the schedule, as shown in Table I, after accepting the application for standard DC of the APR1400 on March 4, 2015. The review process is classified to six steps.

In Phase 1, the U.S.NRC issues request for additional information (RAI) on design control document (DCD) [1], and prepares a preliminary safety evaluation report (SER). In Phase 2, the U.S.NRC issues an SER with open items. In Phase 3, the Advisory Committee on Reactor Safeguards (ACRS) reviews the SER with open items. In Phase 4, the U.S.NRC issues an advanced SER with no open items. In Phase 5, the ACRS reviews an advanced SER with no open items. In Phase 6, the U.S.NRC issues a final SER with no open items.

KHNP has provided successfully the response to RAI, and finished the Phase 1 review in January 2016, which is one month earlier than the U.S.NRC's review schedule. The SER with open items is issued for each chapter, and then the ACRS meeting is held to review it. The first ACRS meeting was held in September 2016, and the ACRS reviews of 7 Chapters (2, 4, 5, 8, 10, 11, 12) were completed by February 2017.

In this paper, overall review results and issues of Chapter 4 on reactor are described.

Table I: NRC Review Schedule

Task	Description	End date (Completed)
Phase 1	Preliminary SER and RAI	Feb. 2016 (Jan. 2016)
Phase 2	SER with open items	Mar. 2017
Phase 3	ACRS review of SER with open items	Jun. 2017
Phase 4	Advanced SER with no open items	Dec. 2017
Phase 5	ACRS review of advanced SER with no open items	Jun. 2018
Phase 6	Final SER with no open items	Sep. 2018

2. Overview of Reactor and Review Results

Table II summarizes the major contents of Chapter 4 on reactor.

Table II: Major Contents of Chapter 4

Section	Major Contents
4.1 Summary Description	Design features for initial core design and summary information
4.1.1	Initial core design description and permissible changes
4.1.2	Analytical techniques
4.2 Fuel System Design	PLUS7 fuel rod and fuel assembly design
4.2.1	Design bases
4.2.2	Description and design drawings
4.2.3	Design evaluation
4.2.4	Testing and inspection plan
4.3 Nuclear Design	Nuclear design of APR1400 reactor system
4.3.1	Design bases
4.3.2	Description
4.3.3	Analytical methods
4.3.4	Changes
4.4 Thermal-Hydraulic Design	Steady-state thermal and hydraulic (TH) analysis of the reactor core
4.4.1	Design bases
4.4.2	Description of TH design of the reactor core
4.4.3	Description of TH design of the reactor coolant system
4.4.4	Evaluation
4.4.5	Testing and verification
4.4.6	Inspection requirements
4.5 Reactor Materials	Reactor material issues
4.5.1	Control rod drive system (CRDS) structural materials
4.5.2	Reactor internals and core support materials
4.6 Functional Design of Reactivity Control System	Control rod drive system

2.1 Key Design Description

The APR1400 reactor is a pressurized water reactor with two reactor coolant loops. Table III contains a summary of the core and fuel design. The reactor core is composed of 241 fuel assemblies and 93 control element assemblies (CEAs). The fuel assemblies are arranged to make a cylindrical batch with an equivalent diameter of 3,647 mm and an active length of 3,810 mm. The fuel assembly, which provides for 236 fuel rod positions (16×16 array), includes four guide thimbles and one instrument tube welded to grids. The top nozzle and bottom nozzle are mounted at the upper and lower parts of the fuel assembly. Each guide thimble displaces four fuel rod positions and provides channels that guide the CEAs over their entire length of travel. In-core instrumentation (ICI) is installed in the instrument tube of selected fuel assemblies. The ICI is routed into the bottom of the fuel assemblies through the bottom head of the reactor vessel.

Table III: APR1400 Core and Fuel Design Summary

Parameter	Value
Core power level (MWt)	3,983
Fuel rod lattice	16 x 16 (236 fuel rods)
Number of fuel assemblies	241
Number of Control Element Assemblies	93
Active fuel length (m)	3.81
Max. peaking factor (Fq)	2.43
Max. fuel rod avg. burnup (MWD/MTU)	60,000

2.2 Review Status of Chapter 4

So far, there are 61 RAI regarding Chapter 4 from the U.S.NRC, and KHNP has responded to 55 RAI, as shown in Table IV. The total number of open items (OIs) identified in the SER is 6. However, all the responses except for Section 4.2 have been submitted to the U.S.NRC, and the number of OIs was reduced to 2 in the ACRS meeting. The open items in Section 4.2 are related to the structural analysis of fuel assemblies for seismic and loss of coolant accident loading.

Table IV: Overview of Chapter 4 Review

SRP Section/Application Section		No. of Questions	No. of OIs
4.2	Fuel system design	14	2*
4.3	Nuclear design	9	0
4.4	Thermal-hydraulic design	8	2
4.5.1	CRDS structural materials	16	2
4.5.2	Reactor internals and core support materials	7	0
4.6	Functional design of reactivity control system	7	0
Total		61	6

* 6 questions not responded were categorized into 1 OI, and other 3 questions were categorized into another OI.

2.3 Key Review Items

2.3.1 Burnup Dependent Thermal Conductivity Degradation

The APR1400 fuel system design safety analysis is based on the use of the FATES-3B fuel design code, which does not contain a burnup dependent thermal conductivity degradation (TCD) model. The U.S.NRC identified concerns regarding compliance with GDC 10 for various fuel system damage and fuel rod damage mechanisms as well as 10 CFR 50.46 for core coolability requirements when the burnup dependency of TCD is not modeled.

The burnup dependent TCD model is addressed in the topical reports "PLUS7 Fuel Design for the APR1400 [3]" and "Realistic Evaluation Methodology for Large-Break LOCA of the APR1400 [4]". The resolution of the DCD Section 4.2 open item depends on the successful completion of these associated topical reports.

2.3.2 Fuel Assembly Structural Response to Externally Applied Loads

During review of the fuel assembly structural response analysis, the U.S.NRC noted that the referenced methodology was not strictly followed in its entirety calling into question the determination of load limits for the PLUS7 fuel assembly. KHNP is in the process of completing its open item resolution plan which includes a complete test program of the PLUS7 fuel assembly and grid for both beginning of life and end of life conditions.

The U.S.NRC has audited the tests as they occur and will be able to review the final analysis documentation when the open item resolution plan has been completed.

3. Conclusions

The APR1400 reactor design of Chapter 4 demonstrates to comply with requirements of federal regulations and the U.S.NRC regulatory documents. Table III shows the summary of the core and fuel design. The SER with open items for Chapter 4 has been issued, and the ACRS meeting to review the SER has been held in February 2017. The resolution plans to key review items have been provided to the U.S.NRC, and they are under addressing as scheduled. Chapter 4 as reviewed and marked-up in response to U.S.NRC's RAI will be incorporated into the next revision of the DCD.

REFERENCES

[1] APR1400-K-X-FS-14002-NP, Revision 0, "APR1400 Design Control Document Tier 2," KHNP, December 2014.
[2] "Advanced Power Reactor 1400 Design Certification Application - Safety Evaluation With Open Items For Chapter 4," U.S. Nuclear Regulatory Commission, January 2017.
[3] APR1400-F-M-TR-13001-P, Revision 0, "PLUS7 Fuel Design for the APR1400," KHNP, August 2013.
[4] APR1400-F-A-TR-12004-P, Revision 0, "Realistic Evaluation Methodology for Large-Break LOCA of the APR1400," KHNP, December 2012.